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BY THE COMPTROLLER GENERAL

Report To The Chairman, Subcommittee On Defense, Committee On Appropriations House Of Representatives

OF THE UNITED STATES

COMPLETED ORIGINAL

Navy Tactical Computer Development--Limited Competition And Questionable Future Software Savings

In September 1980 the Navy awarded contracts for development of new computers for use in tactical digital systems. It received only two bids from the total U.S. computer industry for the development of the computers, and they were from companies which already had major involvement in Navy systems.

GAO found that many computer manufacturers preferred more latitude to determine how to meet a customer's needs than the Navy allowed in its proposals.

Navy planning emphasized getting continued benefit from past software expenditures. Some companies criticized the Navy for making trade offs which limited potential software savings from a new Department of Defense standard programing language the Navy plans to adopt.

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COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON, D.C. 20548

B-202982

The Honorable Joseph P. Addabbo
Chairman, Subcommittee on Defense
Committee on Appropriations
House of Representatives

Dear Mr. Chairman:

In response to your request of September 26, 1980, we are reporting on the Navy's program for development of new tactical computers. You were concerned whether the Navy obtained maximum competition and provided for the early phasein of the new Department of Defense (DOD) standard computer programing language, Ada. Our review results are summarized below. Additional information on the issues involved is provided in appendix I.

The objectives of our review were to determine (1) why the Navy did not get more than two manufacturers to make offers on the AN/UYK-43 and AN/UYK-44 development and (2) if and how well the Navy can implement Ada on the AN/UYK-43 and AN/UYK-44 computers. We also sought to determine what the Navy needs to do in the future to enhance competition and Ada effectiveness. Information on the scope, methodology, and limitations of our review is in appendix I.

For the past several years, the House Appropriations Committee has been urging the Navy to competitively develop and procure new tactical computers to replace the present standard computers. The previous two generations of these computers were obtained from one company. In 1979 the Navy began competitive acquisition of the Navy Embedded Computer System--the AN/UYK-43--and the military reconfigurable microprocessor and microcomputer--the AN/UYK-44--to replace the AN/UYK-7 and AN/UYK-20, respectively, as standard tactical computers.

The AN/UYK-7 and AN/UYK-20 are general purpose computers employed in tactical digital systems and subsystems (i.e., command and control, intelligence, and tactical weapon systems and subsystems).

Their replacements, the AN/UYK-43 and AN/UYK-44, are also general purpose computers that will be used in the same or similar systems and subsystems.

LIMITED COMPETITION

The Navy made a concerted effort to get companies to make offers on the computers the Navy specified. During its decision process, the Navy obtained industry input through conferences, questionnaires, and comments on draft specifications. However, only two companies with present major involvement in Navy systems made offers. These two companies are Univac and IBM.

Univac manufactured all of the AN/UYK-7s and AN/UYK-20s in the Navy inventory. Univac also manufactured a previous generation Navy standard computer, the CP-642 family. IBM performs systems integration work for the Navy and writes software for AN/UYK-7 computer systems. One IBM representative said they have written millions of lines of computer program code for the AN/UYK-7.

Initially, numerous companies were interested in building or developing the AN/UYK-43 and AN/UYK-44 computers. By mid-1980 interest dropped to five companies. When the bidding closed in July 1980, only IBM and Univac made offers on the proposals. In September 1980 the Navy awarded the following full-scale engineering and development contracts:

AN/UYK-43 Computer

Cost-plus-incentive fee

	(millions)
IBM	$20.2
Univac	15.8

AN/UYK-44--Microprocessor and Microcomputer

Fixed price

	(millions)
IBM	$12.1
Univac	10.0

Limited competition resulted for a number of reasons. For the AN/UYK-44 computer, we could identify only three companies that seriously considered making offers but did not. Representatives of these three companies said they did not make offers because of the fixed-price aspect of the contract. These companies felt that development of this computer at a fixed price was too risky. Both companies that did make offers also had reservations about fixed-price computer development.

For the AN/UYK-43 computer, we could identify only one company that seriously considered making an offer but did not. Representatives of this company said they did not want to commit the resources and that to get the specified performance out of the specified architecture would require special hardware configurations. They would rather put their best designers and engineers on a project with less unique and limited application than the AN/UYK-43.

Other factors which company representatives said influenced decisions not to participate and which caused limited competition were (1) overspecification of requirements by the Navy, (2) the risky investment climate at the time, (3) company decisions against capital risk on a development having limited market potential, and (4) uncertain Navy market due to a lack of projected production quantities.

Other companies which were not interested in the AN/UYK-43 and AN/UYK-44 computers criticized the Navy for specifying in too much detail how the Navy needs should be met. Companies which are development oriented said they demand less technological constraint on their initiative. Two companies said the Navy does not need to pay for computer development at all, since there are computers on the market that could be modified to meet the Navy's needs. They believed the Navy should simply state its needs and let competing companies prove their ability to provide needed equipment that is viable and cost beneficial.

QUESTIONABLE FUTURE SOFTWARE SAVINGS

The Navy will be able to use Ada on the AN/UYK-43 and AN/UYK-44 computers but will not capitalize on some economies available in the language design. The Navy plans to use Ada in new systems and major upgrades. The consensus of company representatives we talked to is that these computers will not use Ada efficiently (i.e., they will not be able to fully capitalize on the anticipated software cost savings Ada was designed to yield). These industry representatives said the reason the AN/UYK-43 and AN/UYK-44 will not be able to use Ada efficiently is because the instruction set architectures (ISAs) the Navy specified are not suited to Ada. ISA is the conceptual structure and functional behavior of the machine. The new AN/UYK-43 and AN/UYK-44 ISAs are improved and expanded versions of the present machines' ISAs. The Navy's reason for doing this was to protect its significant investment in software written for the present machines. Thus, Navy planning was driven by the objective to obtain further benefits from past software expenditures.

Representatives of two computer manufacturing companies and one weapons system prime contractor said that manufacturer selection of a modern ISA suited to Ada would not be betting on the unknown future success of Ada. They said a modern ISA would use

the Navy's present language, CMS-2, more efficiently than the Navy's AN/UYK-43 and AN/UYK-44 ISAs will.

NEW COMPUTER NEEDS

Computer industry representatives we talked to were unanimous in their view that the Navy needs new tactical computers because they feel the existing equipment is becoming inadequate. Navy managers agree the need for additional system features, increased requirements, and the need for interoperability among and between Army, Air Force, and other Navy systems have taxed the memory, speed, and throughput of the present computers. Navy personnel responsible for maintaining and testing software directly supporting the fleet stated the need for new computers was immediate to maintain a high level of fleet capability.

The Navy contracted for four independent studies with an objective to determine the optimum time span in which to convert from one Navy computer generation to the next, considering increasing maintenance costs of the old system versus development and hardware costs of a new system. The study reports of April and May 1980 concluded that approximately 5 years was the optimum cycle time. A representative in the Office of the Assistant Secretary of the Navy for Research, Engineering and Systems said that it historically has also taken approximately 5 years from beginning of development to deployment of a Navy computer. Therefore, they have begun to develop a concept for replacement of the AN/UYK-43 and AN/UYK-44 computers. Their objectives in AN/UYK-43 and AN/UYK-44 replacement are (1) increased competition and (2) faster technology infusion.

CONCLUSIONS

Competition for the AN/UYK-43 and AN/UYK-44 computers was limited. We believe the Navy made a concerted effort to get companies to make offers on the computers the Navy specified, as evidenced by continued industry participation in various project stages. However, limited competition resulted for a number of reasons. Many U.S. computer manufacturers prefer more latitude to determine how to meet a customer's needs than the Navy allowed in its proposals. Explicit reasons cited by companies who were initially interested, but did not make offers, were fixed-price development for the AN/UYK-44 and ISA specification for the AN/UYK-43.

The Navy will be able to convert to Ada. It plans to use Ada for new weapon systems programs and major upgrades. However, the consensus of the industry representatives we talked to is that the Navy will not be able to obtain anticipated Ada software economies because the ISAs specified are not suited to Ada. The Navy defined these specified architectures to obtain further benefits from past

software expenditures. Planning should have been directed toward minimizing future life-cycle costs emphasizing Ada implementation.

The current Navy computers are becoming inadequate. Increased requirements for new weapons system applications necessitate new computers to maintain a high level fleet capability.

The Navy has begun to develop a concept for replacement of the AN/UYK-43 and AN/UYK-44 computers. Their objectives are (1) increased competition and (2) faster technology infusion. The industry feels the Navy can best meet these objectives by acting on the following industry criticisms.

--Some companies feel the Navy does not need to pay for computer development because there are computers on the market that could meet Navy needs or be modified to do so.

--The Navy should state its needs and let companies prove their ability to provide needed equipment which is viable and cost beneficial.

--Companies conducting computer development for the Navy want minimum technological constraint on their initiative.

RECOMMENDATIONS

We recommend the Secretary of the Navy

--convert to Ada on a program by program basis in present systems whenever conversion becomes cost beneficial versus maintaining the existing software base and adopting Ada for new programs and major upgrades only and

--employ a concept which states Navy needs with minimum technological constraint and evaluates companies' attempts to prove their ability to provide needed equipment which is viable and cost beneficial, when planning for the follow-on generation of computers to replace the AN/UYK-43 and AN/UYK-44.

We feel that industry will respond with modern architectures which more nearly optimize Ada cost-savings benefits than will the AN/UYK-43 and AN/UYK-44.

As you requested, we did not obtain official agency comments on this report.

As arranged with your office, we are sending copies of this report to the Chairmen, Senate and House Committees on Appropriations and Armed Services, House Committee on Government Operations,

and Senate Committee on Governmental Affairs; the Secretary of the Navy; and to other interested parties.

Sincerely yours,

Milton J. Socolar

Acting Comptroller General
of the United States

ISSUES CONCERNING THE AN/UYK-43 AND AN/UYK-44 COMPUTER DEVELOPMENT-- COMPETITION AND ADA TRANSITION

BACKGROUND

The Navy's use of digital computers at sea began with the Navy Tactical Data System (NTDS) in the late 1950s. One of the first computers in NTDS was the CP-642, built by Univac. The Navy reported that as of May 1980 most of these initial CP-642 computers were still in the inventory. In the early 1970s the Navy began a standardization effort to promote efficiency in logistics, training, reliability and maintainability, configuration control, system interoperability, and software support. The Navy designated the CMS-2 high order language as the standard. The AN/UYK-7 computer was developed as the standard to supersede the CP-642 family. The AN/UYK-7 computer was developed in 1969 under a noncompetitive contract by Univac. All present AN/UYK-7 computers in the inventory, and those still being procured, are built by Univac. As of May 1979, 1,177 bays had been supplied. (A bay is a cabinet containing computer components. An AN/UYK-7 computer is a configuration of one, two, three, or four interconnected bays.) In March 1973 a contract was competitively awarded to Univac to develop the AN/UYK-20 minicomputer for use as a standard in tactical shipboard applications. A noncompetitive, follow-on procurement was awarded to Univac in 1977. As of March 1979, there were 1,894 AN/UYK-20s delivered to or on order by the Navy.

NAVY PLANNING FOR COMPUTERS TO SUPERSEDE THE STANDARD AN/UYK-7 AND AN/UYK-20 SHIPBOARD COMPUTERS

July 1978 master plan for Tactical Embedded Computer Resources

In July 1978 the Director of the Tactical Embedded Computer Program Office of the Naval Material Command drafted a master plan with an objective to "improve and replace our standard computers and support software in an evolutionary manner to meet the changing requirements of the Fleet."

The master plan set out a strategy incorporating these elements:

--Upgrade existing standard computers only to the extent necessary to meet near term user requirements.

--Develop an advanced computer family for future systems.

--Foster maximum use of high order languages (HOL), CMS-2 for the near term, and Ada for the longer term.

1978 Navy Embedded Computer Review Panel

In January 1978 the Assistant Secretary of the Navy for Research, Engineering and Systems established the Navy Embedded Computer Review Panel to develop background information and advise him concerning the Navy's Tactical Embedded Computer Resources Program. The Panel was comprised of Navy, industry, and academic experts.

The Panel recommended that the Navy not implement the sole-source major AN/UYK-7 upgrade, but to develop and deploy a new Navy Embedded Computer System family.

The Panel recognized Navy goals should be increased competition and faster technology infusion than historically experienced. To accomplish these goals, the Panel recommended that the Navy move from standardization on one computer in a performance range to accreditation of a controlled small number of computers in that range as soon as hardware and software technology yield the level of operability needed at sea.

The Panel noted that the costs of software were and will continue to be the dominant costs of computer systems. It urged that software receive significant attention by Navy management.

Finally, the Panel concluded that taking advantage of benefits of HOLs while adhering to ISA compatability to capitalize on existing software developments and to maximize software transportability should be a near term approach. However,

> "for the future the Navy should begin to evolve to complete high order language standardization, lessening the constraints on the internal design of its computers. * * * Secondly, the Navy could seek proposals from industry for a complete hardware/software system which accepts HOL programs and converts them by some means (e.g., compiler) for execution on the computer. The ISA would not be specified. This would allow a vendor different choices as to what combination of compiler, intermediate level language or ISA he felt would best satisfy the HOL."

May 1980 master plan for Tactical Embedded Computer Resources

The Director of the Tactical Embedded Computer Program Office of the Naval Material Command responded to the Panel's criticisms with a revised master plan dated May 14, 1980. The new plan set out elements of the new strategy, such as:

--Competitively develop and procure the AN/UYK-43 computer family as rapidly as possible for shipboard systems which will replicate, as a minimum, the ISA of the AN/UYK-7.

--Competitively develop and procure an AN/UYK-44 reconfigurable microprocessor and microcomputer family which is software compatible with the AN/UYK-20 and AN/AYK-14 and which will provide a standard family member in both the lower and middle performance ranges.

--Use standard HOLs, currently CMS-2, and for the longer term, Ada.

This Naval Material Command plan acknowledged that the Assistant Secretary of the Navy for Research, Engineering and Systems was studying the accreditation concept.

NAVY ATTEMPTS TO OBTAIN COMPETITION

The Navy made a concerted effort to get companies to make offers on the computers they specified. Although the Navy obtained industry input during their decision process, only two companies made offers.

Our assessment required a review of Navy documentation, such as the request for proposals, development contracts awarded to IBM and Univac, and source selection plans. We also reviewed the applicable Navy and DOD regulations on system acquisition and source selection. In addition, we interviewed various contracting and AN/UYK-43 and AN/UYK-44 program office personnel. The following chronology of events outlines the steps taken by the Navy to obtain competition and industry involvement in the AN/UYK-43 and AN/UYK-44 development.

Questionnaires to industry--March 1978

The Navy Embedded Computer Review Panel was organized in 1978 to review the Navy's master plan for embedded computers. An important mandate of the Panel was to develop the necessary background information for advising the Assistant Secretary of the Navy for Research, Engineering and Systems as to the quality and adequacy of the Navy's plans to replace the AN/UYK-7 and AN/UYK-20 computers. The Panel sent out questionnaires to the computer industry to obtain their views on the appropriate courses of action the Navy should consider in embedded computer technology. Fifteen companies responded with their views on such topics as the software advances the Navy should consider, feasibility of dual-source development for the Navy's next computer generation, the length of time for such a development, and so forth.

Industry interest solicited--August 1978

In August 1978 the Navy solicited interest for research and development of the new generation of tactical computers through the Commerce Business Daily publication. The Navy received inquiries from about 40 and 50 companies expressing interest in the AN/UYK-43 and AN/UYK-44 computers, respectively. The companies were sent general program information and concept papers and were advised to submit any questions and/or recommendations regarding the programs.

These questions and recommendations would then be considered when the development of the request for proposals and specifications began.

Development of specifications--
August 1979-March 1980

In late 1979 and early 1980, a Navy Design Review Group, composed of computer programing and software support personnel from the Fleet Combat Direction Systems Support Activities, various Navy laboratories, and the Johns Hopkins Applied Physics Laboratory, developed the specifications for the AN/UYK-43 and AN/UYK-44 computers. During this time frame, interaction between the Navy Design Review Group and industry continued. The draft specifications were released to industry several times for comments. Many of the comments received were considered in the ongoing development of the specifications. According to one Navy official, several modifications to the contractual provisions and specifications resulted from industry recommendations.

Request for proposals issued,
bidders conferences held--
February-May 1980

The formal request for proposal on the AN/UYK-44 was released in February 1980 and on the AN/UYK-43 in May 1980. Shortly thereafter, bidders conferences were held to explain any unclear requirements and answer questions regarding the solicitations. Seventeen companies were represented at the AN/UYK-44 conference and 11 attended the AN/UYK-43 conference.

Project interest declined--March-June 1980

After the bidders conferences, interest in both programs declined. Only five companies continued to express interest in the AN/UYK-44 development; only three remained interested in the AN/UYK-43. At the date for bid closing in July 1980, only IBM and Univac had tendered offers for both developments.

Review of bid proposals--July-August 1980

In the 2 months following the bid closing, the proposals submitted by IBM and Univac were evaluated through the various levels of the Navy's source selection process as dictated by the AN/UYK-43 and AN/UYK-44 source selection plans and Navy regulations. After evaluating the proposals, the Navy offered full-scale engineering development contracts to both companies for each computer development.

Contracts awarded--September 1980

In September 1980 IBM and Univac were awarded contracts for the AN/UYK-43 development in amounts of $20.2 million and $15.8 million, respectively, and for the AN/UYK-44 development in amounts

of $12.1 million and $10 million, respectively. According to milestone data provided us by the Navy in February 1981, production unit delivery for the AN/UYK-43 will begin in December 1984 and for the AN/UYK-44 in November 1983.

INDUSTRY EXPLANATIONS FOR NOT BIDDING

We talked to managers and technical experts of the two companies that made offers and of the three companies that were close to making offers but did not. We asked why they did or did not make offers.

Representatives of three companies that seriously considered making offers on the AN/UYK-44 computer but did not state that their major reason was that the contract was fixed price. They felt that development of the AN/UYK-44 computer at a fixed price was risky. IBM and Univac expressed this same opinion. The Navy contends that it decided on fixed-price procurement to save time because a few companies had a technical headstart toward the AN/UYK-44 and these companies expressed strong interest. We reviewed industry input to the Navy decision process and agree it was reasonable for the Navy to conclude that a fixed-price procurement would not be a disincentive.

We could identify only one company, other than the two that made offers, which was interested in making an offer on the AN/UYK-43. Company representatives said they did not make an offer because they did not want to commit the resources to the project. They elaborated that the computer architecture the Navy specified was constraining because to get the specified performance out of that architecture would require special hardware configurations to make up for architecture deficiencies. They would rather put their best designers and engineers on a project with less unique and limited application--on something more futuristic.

We talked to representatives of two companies that build military computers but were never interested in making offers on the AN/UYK-43 and AN/UYK-44. We also talked to representatives of one commercial computer manufacturing company that was not interested in the defense market. These company representatives, as well as those of some of the five companies most interested in the AN/UYK-43 and AN/UYK-44, talked freely about their own market strategies as well as their perceptions about the market strategies of their competitors. We reviewed industry input to the Navy Embedded Computer Review Panel and the Navy's bidders conferences with manufacturers. From all these sources we determined the reasons why the majority of computer manufacturers in the United States were not interested in the AN/UYK-43 and AN/UYK-44.

Many manufacturers do not build computers on a specified architecture. They either build computers on an architecture they select or may be willing to build a computer on an architecture they select and build in capability to emulate another computer to capture a customer's existing software.

Emulation is a term which means to imitate one system with another such that the imitating system accepts the same data, executes the same programs, and achieves the same results as the imitated system.

Some manufacturers will not build computers to meet stringent military specifications. These "milspecs" are requirements for a computer to operate within tolerance under adverse environmental conditions encountered at sea or on the battlefield.

Representatives of one company said they are not in the market of developing unique computers but sell their off-the-shelf products to the Navy to meet specific needs. They said the Navy does not need to pay for development; computers that could meet some Navy needs already exist. Also, they contend the Navy should specify their needs less stringently than was done for the AN/UYK-43 and AN/UYK-44 and let companies demonstrate that their offerings can meet those needs cost beneficially. In addition, they said, as well as representatives of another technologically progressive company, reliability (1) is the key to minimizing hardware costs and (2) can best be assured by keeping maximum bidders in the game through specifications with the least possible constraints.

NAVY CONVERSION PLANS FOR ADA

The Navy plans to convert to Ada on the AN/UYK-43 and AN/UYK-44 computers. For the present, the Navy plans to maintain its present CMS-2 programing language base. It plans to adopt Ada on a program by program basis for (1) future programs and (2) major upgrades.

In defining ISAs for the AN/UYK-43 and AN/UYK-44 computers, the Navy used ISAs of the present standard computers and improved and expanded upon them. The AN/UYK-43 and AN/UYK-44 ISAs' designs were driven by the objective of maximum use of existing software, much of which is optimized for execution on the old machines.

Software upward compatibility as an objective, when going from one computer generation to the next, is a common management practice. The Navy is attempting to achieve it by building the new computers on the same ISAs as the old computers.

NAVY COMPUTER ARCHITECTURES WILL NOT ALLOW ADA BENEFITS

Manufacturers' criticisms of Navy architectures

The Navy will be able to convert to Ada with the AN/UYK-43 and AN/UYK-44. However, the consensus of industry representatives we talked to is that those machines will not run Ada efficiently and will not capitalize on the design objectives of Ada to yield software cost savings and permit hardware change.

Navy representatives said they have plans for, and have attempted to fund, an Ada compiler for implementing Ada on the AN/UYK-43 and AN/UYK-44. This compiler would be a computer program which translates the HOL program (written in Ada in this case) into machine language so the HOL program may be executed.

We discussed the question of Ada efficiency on the AN/UYK-43 and AN/UYK-44 with

--the two computer manufacturers that made offers,

--one computer manufacturer that seriously considered making an offer but did not,

--two technologically progressive companies that were never interested in the procurement,

--one weapons system prime contractor, and

--a Navy software expert.

All but one of these sources explained that the architectures the Navy specified for the AN/UYK-43 and AN/UYK-44 will not use Ada as efficiently as an architecture more suited to Ada.

Some of these sources explained that the AN/UYK-43 and AN/UYK-44 ISAs are not suited to Ada because an implicit assumption in the definition of Ada is that hardware will absorb some operating systems' software tasks which previously had to be programed in software. Computer companies now working on Ada are trying to implement some operating systems' software and language functions in the hardware. If the hardware architecture selected does not include these assumed tasks, then they must be implemented in software which is less efficient. These sources said that the AN/UYK-43 and AN/UYK-44 architectures would require that such functions be implemented in software. Thus, the AN/UYK-43 architecture will not capture some software cost savings potential designed into Ada.

Ada calls for modern hardware science as well as software science. Ada implemented on an unsuitable architecture does not capitalize on technology. Manufacturers would rather select a more modern architecture that would optimize technology capability to perform certain machine functions implicit in the Ada language definition. Therefore, the AN/UYK-43 architecture stifles manufacturers' initiative regarding hardware solutions to optimize Ada.

The AN/UYK-43 architecture is an expansion of that of the predecessor machine, the AN/UYK-7. The Navy planned this to capture maximum existing software. This concept is commonly employed in industry to get software upwards compatibility from one machine generation to the next. The industry consensus is that changing architectures is a nightmare for a customer. However, one

manufacturer said that you can keep expanding an architecture, but someday you will reach the point where you have got to change to capitalize on new HOL and technology capability.

Another manufacturer said that in specifying an architecture, the Navy made trade offs which favored emulating the AN/UYK-7 rather than enhancing Ada implementation.

The Navy officials we spoke to knew of no Navy analysis of the comparative costs of (1) selecting a new architecture suited to Ada and (2) standardizing on the existing architecture. In the AN/UYK-7 and AN/UYK-20 replacement planning process, the Navy formed the Navy Embedded Computer Review Panel to explore the issues. Three members said the Panel did a simple cost analysis of what it would cost to convert old code if a new architecture was selected for the new computer. The Panel concluded that such a conversion would be too expensive. However, the Panel's report does not address this study or the cost of the alternative selected--maintaining old software and architecture.

By way of comparison, the Army has contracted with Carnegie-Mellon University to develop the "Nebula" architecture for its Military Computer Family. One of the project goals is to develop a standard ISA which exploits current hardware technology and allows evolution through insertion of advancing technology.

The computer engineers who are developing Nebula recently stated in an article 1/ the properties their instruction set should have. It should

> "--raise the level of machine interpretation of the software, where possible, to improve the compilability and performance of high level languages. This implies the use of hardware to absorb some of the burden of providing an efficient language implementation;
>
> "--be implemented in a range of hardware complexities corresponding to the extremes of the computer family [fit all the computers in the family, from the largest to the smallest]; and
>
> "--enhance effective utilization of advancing technologies while maintaining software compatibility.
>
> "The computer architecture--the interface between the hardware and the software--should carefully specify which properties of each are visible to the other. The

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1/"Nebula: A New Architecture and Its Relationship to Computer Hardware," Leland Szewerenko, William B. Dietz, and Frank E. Ward, Jr., IEEE Magazine, February 1981.

hardware or software is free to optimize only those functions which are visible to it and invisible to the other.

"These above properties can be reformulated in terms of two visibility goals. First, the architecture should increase the visibility of program operations to the hardware. This allows hardware enhancement and optimization of these functions. Second, the architecture should reduce the visibility of the hardware to the software, to provide greater freedom of implementation for the hardware designer. This is a divergence from prior generation architectures, in which the entire structure of the hardware, with all its idiosyncracies, was considered available to the software."

If the Navy is to attain its objectives of getting (1) increased competition and (2) faster technology infusion in its tactical computer program, it must follow the modern trend.

Navy contracted study opinion of Navy's architectures

The Navy contracted with four separate non-Navy organizations to recommend a Navy tactical computer replacement program for the future that will result in fleet readiness through increased competition and acceleration of technology infusion. One of these organizations in their report to the Navy said

"The existing AN/UYK-7 and AN/UYK-20 ISAs are approaching architectural obsolescence and do not efficiently support the new DOD Ada language. The use of the existing Navy ISAs is an interim measure and must be followed by introduction of more modern ISAs."

We asked an official in the Navy office that contracted the study to react to that position. He said he asked a study representative why they said that and was told they had the impression that because the computers were old, the ISAs must be outdated. The Navy official said the AN/UYK-43 and AN/UYK-44 architectures are improved and expanded upon versions of the AN/UYK-7 and AN/UYK-20 architectures. This is a common industry solution to get software compatibility in, going from one computer generation to the next.

The same contractor's study made some observations on the Navy's current standardization approach

"* * * every processor has a different instruction set (AN/UYK-20, AN/UYK 7 * * *), and each processor requires its own software support system."

We contrast this to the Army's Military Computer Family's Nebula architecture which is being designed to be used by all the

processors in its Military Computer Family. This Army approach should yield software support systems cost savings.

Our prior report position on cost benefits of Ada and appropriate architectures

In our June 1980 report, 1/ we discussed the results of two recent studies which evaluated architectures using representative performance criteria for military computers and conducted life-cycle cost analyses of those architectures. We reported:

> "* * * the Navy * * * is using the basic architectures of its obsolescent AN/UYK-7 and AN/UYK-20 computers, and its AN/AYK-14 avionics computer which emulates an extended version of the AN/UYK-20 architecture. The Navy is using these architectures to maximize software transferability and to utilize the support software developed for the older computers at a cost of about $90 million.
>
> "The AN/UYK-7 and AN/UYK-20 architectures have not fared well in the various architectural studies. For example, in the Army/Navy computer family architecture selection committee study, the AN/UYK-7 and the AN/UYK-20 scored lowest among the nine architectures evaluated. In the Carnegie-Mellon study completed in July 1978 the AN/UYK-7 finished last, while the AN/UYK-20 scored lower than the PDP-11/780 and the PDP-11/70."

The same report discussed the factors through which Ada benefits can be achieved:

> "* * * Ada, as the standard language, will allow the Department of Defense [DOD] the opportunity to achieve substantial cost savings Defense-wide through software commonality, improved programmer productivity, and new technical features incorporated into its design. Studies conducted in 1977 indicated that nearly $24 billion could be saved from 1983 to 1999 if Ada was implemented Defense-wide."

With the AN/UYK-43 and the AN/UYK-44 computers, the Navy will potentially benefit from standardization on Ada for the sake of standardization alone, that is, software commonality. However, based on the opinion of the majority of our sources in this report that the AN/UYK-43 and AN/UYK-44 architectures are not suited

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1/"The Department of Defense's Standardization Program for Military Computers--A More Unified Effort is Needed," LCD-80-69, June 18, 1980.

to Ada, the Navy will not realize the cost savings potential in programer productivity and new technical features incorporated in the language design.

OBJECTIVES, SCOPE, AND METHODOLOGY

The objectives of our review were to determine (1) why the Navy did not get more than two manufacturers to make offers on the AN/UYK-43 and AN/UYK-44 development and (2) if and how well the Navy can implement Ada on the AN/UYK-43 and AN/UYK-44 computers. We also sought to determine what the Navy needs to do in the future to enhance competition and Ada effectiveness.

We identified the procedures the Navy was required to follow in the procurement process which we reviewed for compliance and sound management practice. Also, we reviewed Navy plans and obtained DOD views on Navy transition to Ada.

We identified at the outset that both the questions of competition and of Ada transition involved the highly complex and controversial subject of what effect did various specific elements in the Navy's specifications have, and hypothetically, if these various specific elements had been different what would have happened? We asked industry representatives these questions.

Many answers we received reflected some degree of particular company market strategy--depending on whether the company would profit or stand to profit from what the Navy does or could do otherwise. Therefore, we limited our use of their views to determining consensus on what the modern trends are, and in some cases, we stated specific company views.

Our evaluation included reviewing planning and program documentation; requirements analyses; various computer industry reports and evaluations; military regulations, instructions, and directives; records and documentation related to the contract administration process; and other pertinent documents.

We discussed the program and concepts with Navy managers and technical experts involved in the replacement program and with other Navy managers in related fields. As requested, however, we did not obtain official agency comments. We discussed the Navy computer replacement with industry executives and technical experts from 10 private sector companies. We also discussed the program with Office of the Secretary of Defense officials. We made our review at the following locations:

--Office of the Under Secretary of Defense for Research and Engineering, Washington, D.C.

--Office of the Assistant Secretary of the Navy for Research, Engineering and Systems, Washington, D.C.

--Defense Advanced Research Projects Agency, Arlington, Virginia.

--U.S. Naval Material Command, Crystal City, Virginia.

--U.S. Naval Sea Systems Command, Crystal City, Virginia.

--U.S. Naval Electronic Systems Command, Crystal City, Virginia.

--Fleet Combat Direction Systems Support Activity, San Diego, California.

--Naval Ocean Systems Center, San Diego, California.

--Integrated Combat Systems Test Facility, San Diego, California.

APPENDIX II

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Congress of the United States
House of Representatives
Committee on Appropriations
Washington, D.C. 20515

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September 26, 1980

Honorable Elmer B. Staats
Comptroller General
of the United States
General Accounting Office
Washington, D. C. 20548

Dear Mr. Staats:

Recently, the General Accounting Office issued a report entitled, "The Department of Defense's Standardization Program for Military Computers - A More Unified Effort is Needed."

For two years, the Committee has been urging the Navy competitively to develop and procure new military computers to replace the AN/UYK-7 and AN/UYK-20. Recently, discussions were held with members of your Logistics and Communications Division staff on this program. Considering the cost and importance of this program, I believe that GAO should monitor its development and provide my Committee with periodic updates. We are particularly interested in assuring that the Navy's program is structured so as to allow maximum competition and to provide the early phase-in of the DoD standard Ada programming language.

It would be appreciated if the initial update, including a briefing, be provided to the Committee early in 1981. Due to the time constraints involved, official comments by the Department of Defense need not be included.

Sincerely,

Joseph P. Addabbo
Chairman
Subcommittee on Defense

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